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Original Article

Waste Assessment Model for an Innovative Engineering Educational Framework: Integrating Lean Management into Outcome-Based Engineering Education (OBEE)

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Abstract - *Engineers have a significant impact on economic development and on all areas of people's lives. The world, in general, and industry in particular, face more challenges due to technological and economic changes. Thus, skilled engineering graduates with a deep understanding of technical complexities, creative methods, and personal attributes are highly needed in the industrial field. This paper introduces a novel and hybrid educational model structured into five layers. The model combines two approaches: Outcome-Based Engineering Education (OBEE) and Lean Management. Industrial Lean Management principles and methods are adapted to each layer to make the OBEE process more efficient and effective. Before introducing the proposed Lean-OBEE model, a thorough analysis was conducted through a Waste Assessment Model (WAM) to pinpoint inefficiencies in the current educational system. This was the starting point for structuring the hybrid educational model to improve students' outcomes and eliminate waste. This paper presents specifically the first layer's architecture that emphasizes the development of Course Outcomes (COs).*

Keywords - *Course Outcomes, Educational Model, Lean Management, Outcome-Based Engineering Education, Waste Assessment Model.*

1. Introduction

Engineering stands as the cornerstone of any advanced civilization and human progress. It is a broad field that uses scientific concepts and knowledge to design, manage, create, and maintain systems, processes, and structures. In general, engineering can be defined as the application of technical capability and scientific knowledge to solve intricate problems. The process of attaining structured and scientific knowledge, skills, and competencies relevant to the professional practice of engineering is known as engineering education [1, 2].

The constant technological and industrial revolutions characterize our current society. Engineering education faces a significant challenge in meeting the changing demands of the contemporary job market [1]. While industries embrace automation, digitalization, and artificial intelligence, such university programs are still grounded in traditional and theory-driven approaches that often struggle to prepare future engineers with the skills needed to handle the complex and interdisciplinary problems of the real world. Ensuring the relevance, consistency, and reliability of engineering programs and pedagogical methods is the current issue. Future engineers should be adequately equipped with the skills required for innovation, adaptability, and sustainable performance [1]. Limited studies have highlighted the necessity to adopt such approaches to meet this need. These studies do not cover each level of engineering education. The present study proposes a thorough model that addresses all aspects of the learning process, including strategic planning, educational practice, assessment, and continuous improvements [2-5].

To bridge the existing gap, it is essential to refine and customize engineering education by integrating innovative and adaptive teaching methods that align learning with the evolving landscape of professional practice. The present research intends to provide a new contribution to the Lean Management approach by extending its principles and methods from the industrial sector into engineering education. The research objective is to develop an educational framework that integrates Lean Management principles, especially those related to continuous improvements, value addition, and elimination of waste into the OBEE system. The suggested framework allows promoting a culture of continuous improvements in curriculum design and teaching practices, ensuring relevance, efficiency, and adequacy with the industry expectations and the dynamic needs of diverse stakeholders.

Outcome-Based Engineering Education (OBEE) is a student-centered educational approach that reforms curriculum, assessment, and educational practices to ensure that graduates have the knowledge and abilities necessary to become successful professionals once they complete the academic program [6]. OBEE emphasizes the students' learning by [7]:

- Using student learning outcomes to make clear what knowledge or skills students should possess;
- Providing learning positive activities to assist students in achieving the learning outcomes;
- Assessing the extent to which students achieve these outcomes through the use of explicit assessment criteria.

Furthermore, OBEE implementation demands the adoption of corporate best practices to deploy new initiatives that streamline the educational activities and ensure the sustainability of the improved process.

Lean Management is an agile approach mainly used in the industry to remove waste and enhance productivity and efficiency. Lean practices are rooted in the latter 19th century and the early 20th century, in the manufacturing sector. They have also continually evolved to become more accessible and understandable for individuals without specialized backgrounds in industrial engineering. This has enabled a wide range of people from varied fields and interests to become proficient practitioners of Lean Management [8]. Among the most significant advantages of Lean Management is its inclusivity. The Lean principles are similarly accessible and applicable to everyone and each level of the organization. This accessibility allowed Lean practices to be adopted broadly across many industries, such as construction, banking, and healthcare [9].

The main contribution of this research is to apply Lean Management principles and methods to the educational system for improving students' performance and promoting learning outcomes. In previous studies [10-19], Lean Management has been primarily implemented for administrative processes and the management of student activities. However, in this study, Lean Management is implemented to detect and analyze inefficiencies in the existing educational system and support the practice of teaching and learning, including curriculum design and pedagogical activities. Firstly, this paper suggests a Lean Waste Assessment Model (WAM) to determine and assess waste in the learning process. This serves as a diagnostic tool to pinpoint the waste and gaps within the current educational framework.

Based on the literature review conducted, only one study introduced Lean Management with the OBEE approach [20]. This work presented this integration indirectly by structuring the OBEE framework according to the PDCA cycles of Lean Management.

The present study, however, takes this perspective further by developing a hybrid educational model structured into five layers.

This model is also based on the PDCA of continuous improvements and integrates Lean principles and methods throughout every layer of the OBEE process deployment, including [6]:

- Strategic planning: setting goals, timelines, structure, roles, and responsibilities;
- Educational practices and strategies: Curriculum design, program mapping, faculty training;
- Assessment and Evaluation: Assessment plan, assessment tools, and stakeholders' participation;
- Continuous improvements: Follow-up and completion of the action plan, with validation from stakeholders.

Applied in OBEE architecture, Lean Management improves learning effectiveness by continually optimizing processes and making sure that all elements of the curriculum and educational activities contribute to student success.

2. Literature Review

2.1. OBEE Approach

Outcomes, as defined by OBEE, refer to the expected demonstrations of knowledge or skills that students should exhibit following a significant educational experience.

They are the actions that reflect students' ability to effectively apply knowledge and use resources [6, 21].

The OBEE objective is to ensure that students attain a whole set of knowledge, skills, and attitudes required for achievement upon the completion of academic education. OBEE is an educational approach that focuses on enhancing learners' future performance abilities and using knowledge to reach desired outcomes post-instruction. The OBEE framework, shown in Figure 1, includes the following key elements: Vision and Mission, Program Educational Objectives (PEOs), Program Outcomes (POs), and Course Outcomes (COs) [6].

Course Outcomes (COs) are detailed statements regarding the knowledge, skills, and attitudes students are supposed to possess by the end of a specific course. In general, they are considered to support and correlate with the POs and to be expressed in measurable and observable terms. COs are basically about what the learners can demonstrate or perform by completing a course.

Program Outcomes (POs) are specific statements that outline the abilities and competencies students should acquire upon graduation. POs describe students' knowledge, skills, and behavior while progressing through the program and upon graduation. POs must be aligned with the Graduate Attributes (GAs). GAs are a set of generic learning outcomes that are expected from graduates. These attributes are internationally recognized to emphasize technical knowledge, skills, professional behavior, and ethical practices [6].

Program Educational Objectives (PEOs) are concise statements of knowledge that graduates should possess. They are typically developed within a few years after graduation. PEOs are defined as features or precise goals describing the desired achievements of graduates in their professional careers after graduation. Those goals are in sync with the vision and mission that the institute prepares in collaboration with the stakeholders (students, alumni, industry experts, etc.). PEOs generally include broad outcomes about the areas of expertise, employment, professional activity, continuing education, leadership, and team activity.

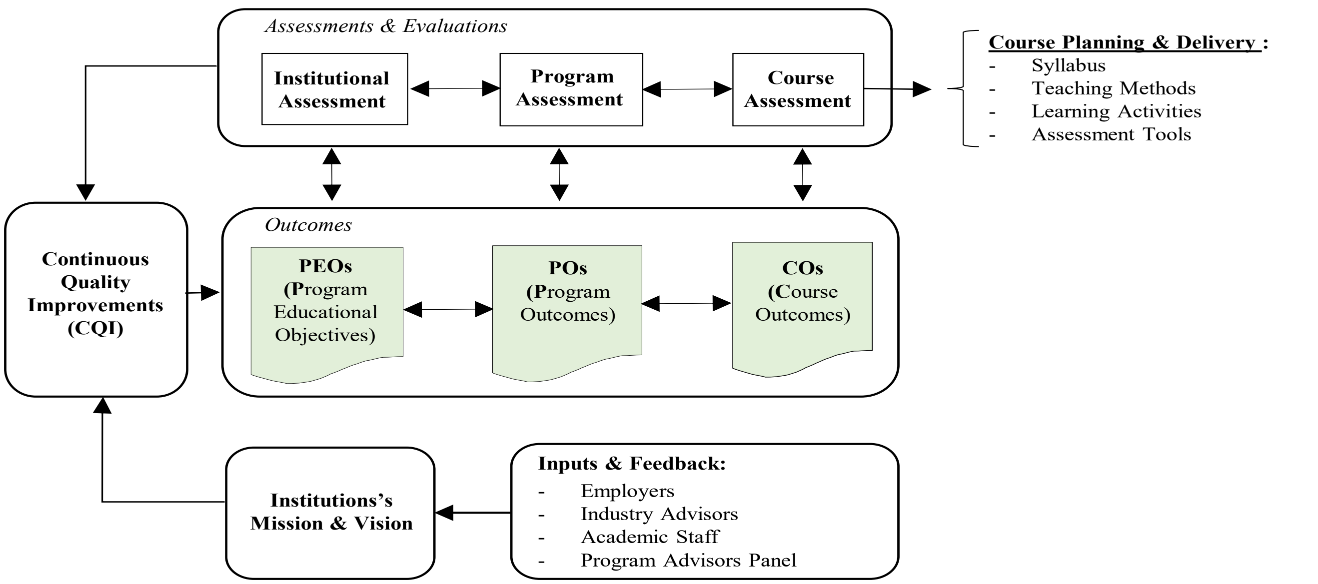

Fig. 1 Key features of the OBEE approach

Vision is a forward-looking statement of what the institution would like to achieve in the long term. Mission is the proposed means to move toward the stated vision. The vision statement focuses on the future and outlines the institute's ultimate aspirations. The mission statement highlights the present and describes the actions taken by the institute to reach those goals.

2.2. Lean Management Approach

Over the past several decades, various industries have adopted Lean Management as a solution for enhancing operational efficiency and overall performance.

It is initially rooted in the Toyota Production System (TPS), which focuses on attaining operational excellence. Lean Management is an approach that promotes continuous improvements in the workplace through efficient use of resources [22].

Lean Management, as a philosophy, applies a set of methods and principles to eliminate waste. Waste refers to any activity that does not contribute to the value of the end product or service, thereby failing to fulfill customer needs.

Lean Management enables the streamlining of processes, the better utilization of human and material resources, more efficient production activities, higher quality standardization, and continuous production time to improve overall performance.

The MUDA: Over-production, Waiting, Transportation, Extra-processing, Inventory, Motion, Defects, and Non-utilization of talents, are the eight categories of waste, identified by Lean Management [23].

The Lean principles are the following [8]:

- Customers define value because they ultimately pay for the product.
- Value Stream: defines all of the steps needed to convert raw materials into the final product.
- Flow: Products flow smoothly through each step of the process without delay and are produced at a rate that meets customer demand.
- Pull Flow: Provides what is required by the customer or the next step in the process.
- Pursuing Perfection: Always looking for improvements, trying to be better all the time.

2.3. Lean Management in Higher Education

Applying Lean principles and tools, Emiliani [24] designed and delivered a graduate-level business school course. The study highlighted the potential of Lean principles for enhancing educational settings. In addition, Emiliani [25] discussed the application of kaizen in a 30-credit, part-time master of Science degree in management program for working professionals. The Team members recognized several advantages of kaizen that generally do not exist in conventional methods for identifying, deploying, and evaluating improvement opportunities.

Hines and Lethbridge [10] presented both the advantages of the Lean methodology in higher educational institutions and the challenges of establishing a Lean culture in this setting. Alagaraja [11] introduced clean-cut and precise theoretical frameworks designed for adult learning programs. Bozkus [12] proposed a five-step procedure for integrating Lean principles in education to improve processes, reduce costs, and enhance the quality of service.

Through a creative and engaging learning experience involving undergraduate students, Doman's [13] study showed that Lean concepts and practices can be successfully implemented to enhance processes of administration in higher education. Douglas et al. [14] explained how to translate the MUDA of Lean thinking into Higher Education Institutions (HEIs), including examples of wastes observed in HEIs. Lean methods such as 5S, just-in-time production and delivery, and process mapping are proposed to identify these wastes.

Kazancoglu and Ozkan-Ozen [15] examined the MUDA of Lean Management in HEIs by providing a framework for HEI administrators and stakeholders who attempt to identify, analyze, classify, and understand waste and sub-waste types for HEIs. Mulyana et al. [16] proposed a WAM to identify waste types most critical to be eliminated in HEIs and uncover the root of each waste. Höfer and Neave [17] emphasized the applicability of Lean Management principles, particularly in relation to waste elimination and customer orientation, to enhance the efficiency of universities. They noted that strong leadership commitment is essential to promote Lean culture in the academic and administrative processes.

Dinis-Carvalho and Fernandes [26] described a model based on the application of Lean concepts, especially PDCA cycles, to teaching and learning in higher education and analyzed student feedback and its effectiveness. Bhat et al. used PDCA cycles to enhance OBEE implementation [20]. Sremcev et al. [27] suggested using the 5S as a Lean method to eliminate waste in the planning, preparation, and execution of the teaching process. Several studies proposed models to assist HEIs in implementing the principles of Lean Management to deal with educational issues [18, 19, 28].

3. Research Methodology

This paper holistically examined the challenge of providing comprehensive, high-quality engineering education at the government policy level to meet the need for industrial skilled engineers. The focus is on the teaching and learning process rather than other administrative processes.

This research is based on action research methodology, a participatory and iterative process that enables active involvement of all stakeholders (teachers, students, alumni, industry, etc.) in teaching improvements and assessments. The aim is to establish an innovative hybrid teaching model for implementing the OBEE approach and Lean Management in the educational settings [20]. The proposed model comprises a structured OBEE architecture divided into five layers [29]. This framework offers a systematic approach to crafting and aligning educational outcomes (COs, POs, and PEOs). Lean Management methods and principles have been adapted for each layer (Figure 2).

To effectively carry out the action research and to come up with a robust framework for the proposed educational model, it is imperative to begin with a thorough analysis by developing a WAM based on the eight Wastes of Lean Management (MUDA). The WAM is designed to assess the effectiveness of training provided by the National School of Applied Sciences (ENSA) to industrial and logistics engineers and determine the MUDA of its academic programs. Based on the results obtained from this assessment, the educational Lean-OBEE model was proposed. Only the first layer of the five-layer model is presented.

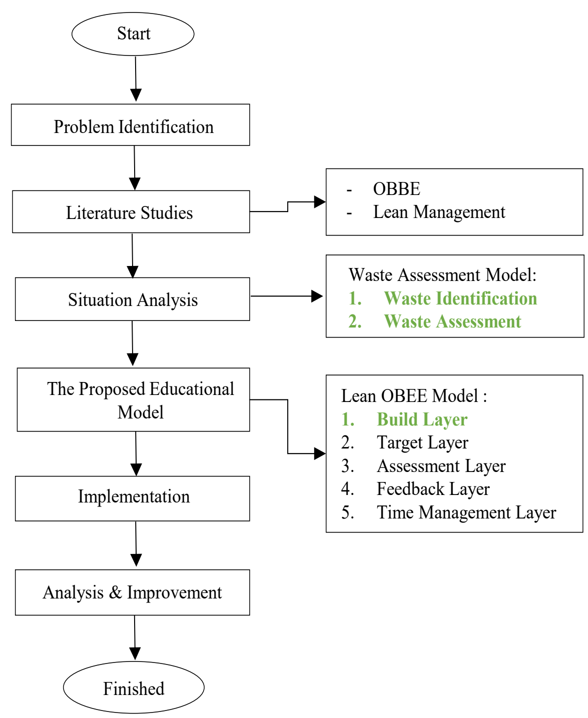

Fig. 2 Steps and methods of the study

3.1. Waste Assessment Model (WAM)

According to Rawabdeh [30], the WAM was developed to determine critical types of waste and seek solution strategies for their elimination. Waste identification includes multiple questions designed to identify specific types of waste by collecting feedback from industrial employers regarding the quality of the educational programs and assessing their effectiveness in adequately meeting academic and professional standards. Waste types interrelate; each category of waste (MUDA) affects and is affected by other categories, although the relations might have different importance grades. The waste relationships are rated using a questionnaire (Table 5), with weights ranging from zero to four [16, 30].

3.2. Lean-OBEE Articulation

Lean Management and OBEE focus on process optimization and measurable outcomes.

Based on the literature review conducted, Table 1 outlines the correspondence between the key principles and concepts of Lean Management and OBEE.

Table 1. Lean OBEE analogies

Lean Management Principles	OBEE Principles
Customer Focus: Lean emphasizes meeting customer needs efficiently	Student-Centered Approach: OBEE focuses on meeting student learning outcomes effectively and industry needs
Continuous Improvement: Lean encourages ongoing improvement in processes	Continuous Assessment: OBEE promotes continuous assessment and feedback for educational improvement
Waste Reduction: Lean aims to reduce waste in processes	Elimination of Non-Essentials: OBEE seeks to eliminate unnecessary curriculum components and focuses on essential learning outcomes
Value Stream Mapping: Lean uses such methods to identify activities and optimize processes	Learning Outcome Mapping: OBEE involves mapping the desired learning outcomes to ensure alignment with educational outcomes
Just-In-Time (JIT): Lean uses JIT to produce goods or services exactly when needed	Learning On Demand: OBEE encourages learning on demand, aligning learning activities with the student's needs and pace.
Standardization: Lean involves standardizing processes for efficiency	Outcome Standardization: OBEE includes defining standardized learning outcomes to ensure consistency and quality in education
Respect for People: Lean values the contributions of employees	Student Empowerment: OBEE values student input and encourages them to participate actively in their learning progress
Cross-Functional Teams: Lean encourages collaboration across departments	Collaborative Learning: OBEE emphasizes collaborative learning experiences and interdisciplinary approaches
Visual Management: Lean uses visual tools for better communication	Transparent Communication: OBEE promotes transparent communication of learning objectives and expectations
Error Reduction: The Lean Management objective is to minimize mistakes in operational activities	Focus on Mastery: OBEE is devoted to making sure students know the fundamental concepts thoroughly before moving to higher levels, equipped with the skills necessary for employment.

3.3. DELPHI Method

The Delphi technique is a structured process where panels of experts and experienced professionals generate a reliable and valid consensus through a series of questionnaires and controlled feedback [31]. Such a method should be used in education to predict trends and establish guidelines. This is especially helpful for teachers who are seeking to design learning experiences regarding students' careers, as it allows the universities to gather data and information from students, alumni, experts, and professionals about their curriculum and educational programs.

3.4. Visual Management

Visual Management is an organizational model that promotes the application of sensory information techniques to enhance the wide-ranging information flow in the workplace. It is a Lean tool that makes important information accessible and visible to everyone [32]. Visual Management enhances the capacity of stakeholders for self-management, communication, and transparency.

4. Model and Results

4.1. Situation Analysis: Waste Identification

Most of the current research studies that applied the Lean waste model are focused on identifying waste associated with administrative processes in higher education and inefficiencies that occur outside direct educational delivery.

The proposed approach differs from these studies by focusing the analysis on the academic core, assessing how training quality and teaching practices influence the overall educational experience. The questionnaire consisted of two main sections. The first section refers to general information, having the purpose of outlining the profile of the sample (32 industrial & logistics engineers). It includes questions related to the activity sector as well as the job position that the industrial and logistics engineer holds in the company. This information is very important for the contextualization of data and drawing inferences between the professional characteristics of the participants and the findings of the study (Figures 3 and 4). The second section includes the eight MUDA questions that break into 16 questions (Table 2). The questionnaire is intended for industrial directors and managers (production, maintenance, projects, purchasing, and continuous improvement) who are employers of engineers graduating from the industrial engineering and logistics section of the ENSA (Figure 5 and Table 3). The Automotive and Heavy Industry sectors dominate, each accounting for 31% of the total responses. This indicates a strong presence of these sectors in the current industrial landscape. Sectors such as Consulting and Public Industrial Institutions each account for 9%, followed by Aeronautics at 6%. Less represented sectors include the Agri-Food Industry, Pharmaceutical Industry, Textile Industry, and Services, which contribute only 3%.

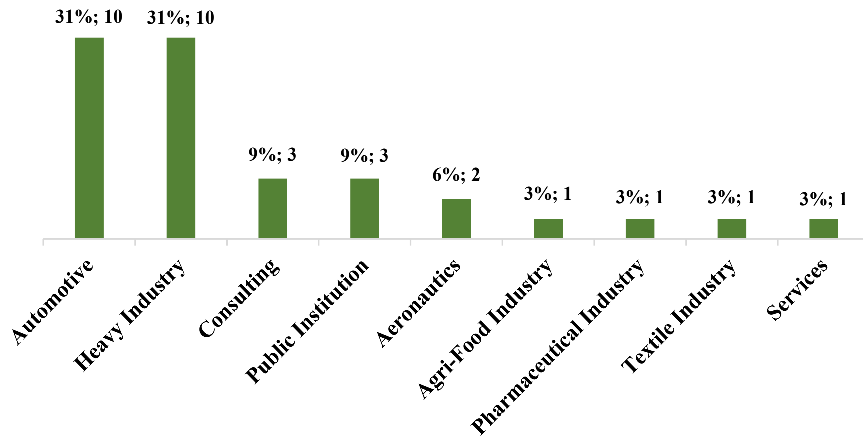

Fig. 3 Distribution of responses by sector of activity

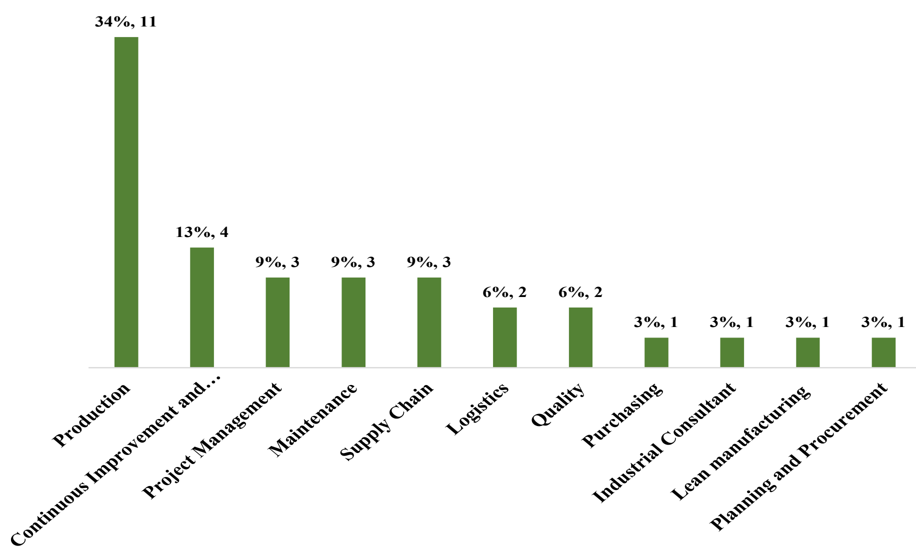

Fig. 4 Distribution of responses by job positions

Production is the most common work position, accounting for 34% of the responses. This fits with the most common types of industries (Automotive and Heavy Industry), where production activities are central. Continuous Improvement/ Operational Excellence follows at 13%, indicating growing interest in performance improvement roles. Project Management, Maintenance, and Supply Chain each account for 9%, showing a reasonable distribution across key industrial activities. Logistics and Quality account for 6%. Functions such as Purchasing, Industrial Consultant, Lean Manufacturing, and Planning & Procurement are less represented, each at 3%. These results will guide and frame the design of training programs within the framework of the proposed educational model.

Table 2. Waste assessment questions

No	MUDA	Non-Value Activities (Questions)
1	Overproduction	Does the academic training for industrial and logistics engineers lead to an overproduction of graduates with skills that are not required or aligned with the current industry needs?
2		Are the aspects of the training program unused in the professional careers of industrial and logistics engineers?
3		Is there a rise in the number of industrial and logistics engineers relative to your industry's current job market demands?
4	Waiting	Do graduates need additional training to make them fully operational as soon as they are recruited? If that is true, which ones? (*)
5		Do recruitment times get longer because candidates lack specific skills? If that is true, which ones? (*)
6	Transportation	Does your company not coordinate or transfer information about the skills and knowledge needed for industrial and logistics engineers to academic institutions? If so, how? (*)
7		Do you find the exchange of information between the educational institution and the industry ineffective?
8	Extra-processing	Does the training include theoretical aspects not directly applicable to the industry? (*)
9		Do you think there are areas of specialization or subjects in industrial and logistics engineering training that could be simplified or reduced without affecting the overall quality of the training?
10	Inventory	Are there any examples of situations where industrial and logistics engineers are trained in obsolete technologies or methods? (*)
11		Does the academic training for industrial and logistics engineers contribute to an unnecessary accumulation of knowledge or skills among students? (*)
12	Motion	Do you think that the regular changes to industrial and logistics engineering courses have a positive impact on the quality of the training? (*)
13	Defects	Have you identified any gaps in graduates' skills or knowledge that impact their professional performance? (*)
14		Do you think the training acquired by industrial and logistics engineers does not adequately meet your needs?
15		Do you think that industrial logistics engineering training programs prepare students to perform exceptionally well in their work?
16	Non-utilization of talents	Do you think that industrial and logistics engineering training programs could lead to the production of engineers that the industry does not actually need? (*)

*: Open-ended questions, Rationale for the answer, or comment

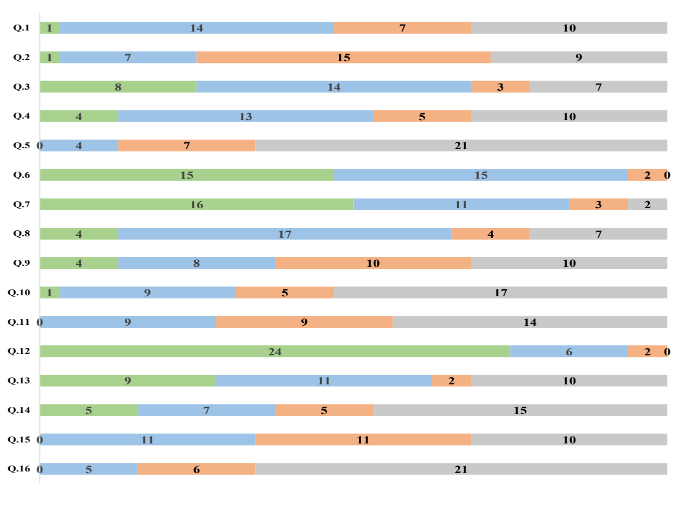

Fig. 5 Respondent's answer

Table 3. Comments/Responses to open-ended questions

Category of waste	No	Open-ended answer or Rationale for the answer
Waiting	4	• Soft skills: Communication, problem-solving, teamwork, leadership, management • ERP (Enterprise Resource Planning): SAP, SAGE, ORACLE • Project management • Lean manufacturing • IT tools • Industry 4.0 and 5.0 • Software knowledge & use • Data science • Behavior laws materials • Norms & Qualifications • Artificial intelligence
Waiting	5	• 3D Printing • Additive manufacturing • Soft skills: Negotiation skills and supplier relationship management, flexibility, adaptability, and resilience.
Transportation	6	• Strategic Workforce Planning (SWP) • Training Program for Newly Recruited Engineers
Transportation	7	The effectiveness of the interactions between an educational institution and industry can be assessed by the relevance and currency of academic programs, the strength of the partnerships formed, and the provision of internships and collaborative projects that meet the specific needs of the market
Extra-processing	8/9	• Module of "Communication Techniques and Expressions" • Including the Industry 4.0 module is important, as it aligns with current trends and priorities for the majority of industries • The theoretical modules of the integrated preparatory cycle and the first year of the engineering cycle, which are common to the other disciplines, require a considerable amount of time, unlike the practical specialty modules, which are taught at the end of the course • Some modules would be more effectively taught through projects, simulations, case studies, or presentations, such as Supply Chain Management, Project Management, Production Management, etc. • An industrial engineer needs to be well-versed in management. Therefore, it is essential to cover this aspect in the training program rather than concentrating only on technical skills.
Inventory	10	• Software for simulation and calculation (SAP, Prelude, SIMATIC, …) • Project management methods • Production management
Inventory	11	Some courses focus on theory without providing enough opportunities for practical case studies.
Motion	12	Constant updates in industrial engineering education enhance the quality of training by keeping the curriculum relevant and responsive to emerging industry trends. By incorporating contemporary tools, methodologies, and knowledge, these programs align more closely with the demands of the job market. This means that the students are getting practical and modern skills, which lead to their employability and make them ready to handle real-life problems. Regular changes in the assessment will also help the industrial engineers to cope with future challenges and to be up to date in a field that is rapidly changing.
Defects	13	• Soft skills can be a hurdle for graduates • The link between theory and practice • Management skills need to be developed
Non-utilization of talents	16	• Especially in the automotive and aerospace sectors • If the current training remains unchanged in its content without adapting to the evolution of the industry, it will likely hinder the development of relevant skills and reduce the competitiveness of professionals in the field

The survey comments collected from industry employers emphasized the need for a responsive education system to meet the evolving requirements of the labor market (critical thinking, digital literacy, adaptability…). Employers identified a gap between the skills gained and the skills demanded in the labor market. Thus, they suggested the use of more interactive models, which can effectively combine the two areas of academic excellence and professional practice. The employers also pointed out that industry-university interactions will significantly influence the quality of partnerships formed, the availability of internship opportunities, and corporate activities that meet the needs of the labor market.

4.2. Reliability Test

To consider the results of a questionnaire as valid, it is imperative to assess the stability and consistency of responses from the questionnaire participants. This ensures the reliability of the questionnaire in generating reliable results if it is conducted under the same conditions again. A reliability test was conducted with the Statistical Package for the Social Sciences (SPSS) software, which calculated the Cronbach alpha coefficient. The obtained Cronbach Alpha value is 0.742, which exceeds the usual level of acceptability. This confirms that the questionnaire responses are reliable [16].

Table 4 presents the main waste that affects the adequacy and effectiveness of academic training in meeting the labor market's requirements. Overproduction, Transportation, and Defects emerged as the top-ranked wastes. Wastes, including Extra processing, Waiting, Motion, Inventory, and Non-utilization of talents, have less impact than others.

Table 4. Rank of waste

MUDA	Total Score	Rank
Overproduction	221	1
Waiting	122	5
Transportation	214	2
Extra-processing	152	4
Inventory	117	7
Motion	118	6
Defects	214	3
Non-utilization of talents	48	8

4.3. Waste Relationship Matrix (WRM)

It is essential to identify the significant waste that has the most considerable effect on the training process of industrial and logistics engineers. WAM is used to examine the interdependence between various forms of waste. All categories of waste are interconnected; each type affects and is affected by other types of waste.

This relationship is complicated as the effects of each can be exhibited directly and indirectly. Following the results of Rawabdeh [30] and brainstorming sessions conducted with industrial employers of industrial and logistics engineers, a model was developed to present the relationship between waste categories, as shown in Figure 6.

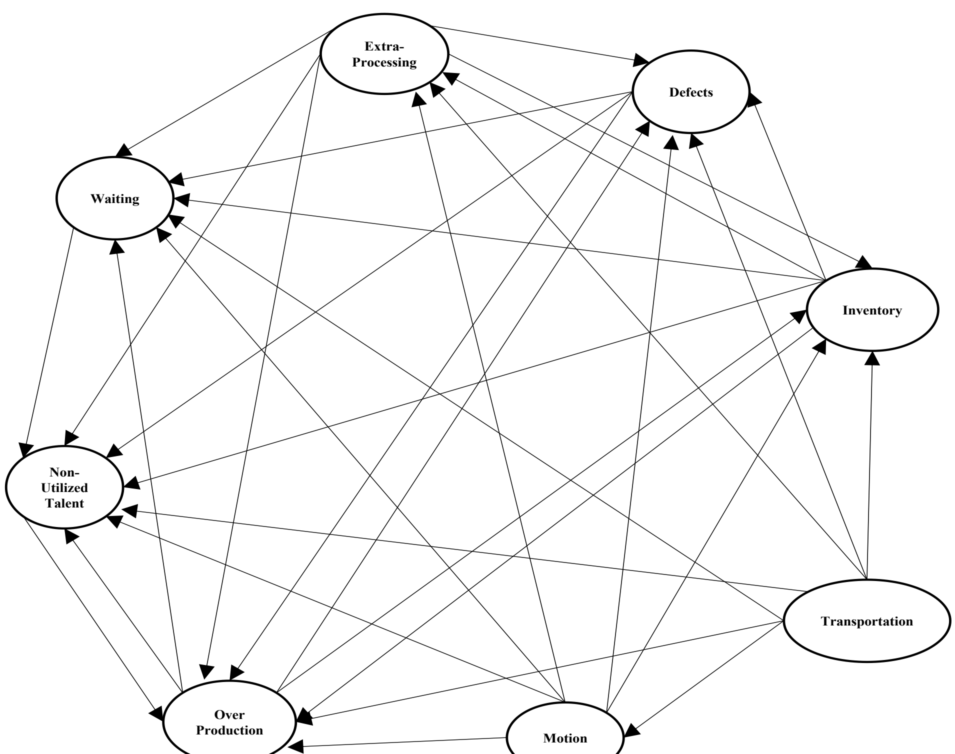

Fig. 6 The relationships of the eight MUDA

The data for waste relationships were gathered using the questionnaire developed by Rawabdeh [30]. This questionnaire has been adapted to the context of this study to assess the effect of one waste type on the other (Table 5). The questionnaire was exclusively given to industrial employers. The analysis was done based on feedback collected from these employers.

Each question in the questionnaire had an assigned weight, which was used to calculate the total weight for determining the relationship between different waste types (Table 7). Based on the total weight obtained from each type of waste relationship, a conversion from weight to symbol was conducted [30] (Tables 6 and 7).

Table 5. Waste relationship questionnaire

Question	Weight
(1) Does waste “m” generate “n” in the education process?	
Always	4
Sometimes	2
Rarely	0
(2) What kind of relationship exists between "m" and "n"	
As “m” increases, “n” also increases	2
As “m” increases, “n” reaches a constant level	1
Random, depends on the conditions	0
(3) The impact of “n” due to “m”:	
Appeal immediately and clearly	4
Takes time to appear	2
Does not often appear	0
(4) Eliminating the effect of “m” on “n” can be achieved by:	
Appropriate educational model	2
Appropriate teaching methods	1
Organizational or administrative solutions	0
(5) The impact of “n” due to “m” primarily affects:	
Quality of learning	1
Alignment of curriculum with industry needs	1
Students' productivity	1
Quality of learning and Alignment of curriculum with industry needs	2
Quality of learning and students' productivity	2
Alignment of curriculum with industry needs and students' productivity	2
Quality of learning, Alignment of curriculum with industry needs, and students' productivity	4
(6) To what degree does the impact of “m” on “n” increase graduate employability and job market readiness?	
High	4
Medium	2
Low	0

Table 6. Levels of strength for the direct relationship range

Range	Symbol
From 17 to 20	A
From 13 to 16	E
From 9 to 12	I
From 5 to 8	O
From 1 to 4	U
0	X

Table 7. Score calculation of waste relationship matrix

N°	Relationship	1	2	3	4	5	6	Score	Level
1	O_I	4	2	4	2	4	2	18	A
2	O_D	2	2	4	2	2	2	14	E
3	O_Ta	4	2	2	2	2	4	16	E

4	O_W	4	2	2	2	2	2	14	E
5	I_D	2	2	4	2	2	2	14	E
6	I_P	2	2	4	2	2	2	14	E
7	I_W	4	2	2	2	2	2	14	E
8	I_Ta	2	0	2	2	2	2	10	I
9	I_O	2	2	4	2	2	2	14	E
10	D_O	2	2	2	2	2	2	12	I
11	D_W	4	2	4	2	2	2	16	E
12	D_Ta	4	2	4	2	2	4	18	A
13	M_O	2	0	2	2	4	2	12	I
14	M_I	2	0	2	2	4	2	12	I
15	M_D	2	0	2	2	4	2	12	I
16	M_P	2	0	2	2	4	2	12	I
17	M_W	2	0	2	2	2	2	10	I
18	M_Ta	2	0	0	0	2	2	6	O
19	T_O	2	2	2	2	2	2	12	I
20	T_I	2	2	2	2	2	2	12	I
21	T_D	4	2	4	2	2	2	16	E
22	T_M	2	0	2	0	2	0	6	O
23	T_P	2	2	2	2	2	2	12	I
24	T_W	4	2	4	2	2	2	16	E
25	T_Ta	2	2	2	0	2	2	10	I
26	P_O	2	2	2	2	2	2	12	I
27	P_I	4	2	4	2	2	2	16	E
28	P_D	2	0	2	2	2	2	10	I
29	P_W	2	0	2	2	2	0	8	O
30	P_Ta	2	0	0	2	2	0	6	O
31	W_Ta	2	0	0	2	2	0	6	O
32	Ta_O	2	2	2	2	2	2	12	I

As presented in Table 7, each letter represents a type of waste: O stands for Overproduction, I stands for Inventory, D stands for Defects, M stands for Motion, T stands for Transportation, P stands for Extra-processing, W stands for Waiting, and Ta stands for Non-utilized talents. The analysis of the measurement criterion is summarized in the Waste Relationship Matrix (WRM), as shown in Figure 7. Then, the relationship value is obtained from the WRM table by substituting letters with numbers, i.e., A=10, E=8, I=6, O=4, U=2, and X=0 [30].

Using this waste relationship value, one can quantify the value of each waste percentage for the "from" and "to" types. The waste relationship value is presented in Table 8. Table 8 outlines the types of waste and their impacts on the appearance of other types of waste. Transportation has a "From" score of 18.49%. This indicates that Transportation most significantly contributes to the appearance of other types of waste. Next comes Inventory waste, which has a notable impact at 16.44%. Motion and Over-production are rated at 15.07%.

F/T	O	I	D	M	T	P	W	Ta
O	A	A	E	X	X	X	E	E
I	E	A	E	X	X	E	E	I
D	I	X	A	X	X	X	E	A
M	I	I	I	A	X	I	I	O
T	I	I	E	O	A	I	E	I
P	I	E	I	X	X	A	O	O
W	X	X	X	X	X	X	A	O
Ta	I	X	X	X	X	X	X	A

Fig. 7 Waste relationship matrix

Table 8. Waste matrix value

F/T	O	I	D	M	T	P	W	Ta	Score	Score (%)
O	10	10	8	0	0	0	8	8	44	15.07
I	8	10	8	0	0	8	8	6	48	16.44
D	6	0	10	0	0	0	8	10	34	11.64
M	6	6	6	10	0	6	6	4	44	15.07
T	6	6	8	4	10	6	8	6	54	18.49
P	6	8	6	0	0	10	4	4	38	13.01
W	0	0	0	0	0	0	10	4	14	4.79
Ta	6	0	0	0	0	0	0	10	16	5.48
Score	48	40	46	14	10	30	52	52	292	100
Score (%)	16.44	13.70	15.75	4.79	3.42	10.27	17.81	17.81	100	

These four types of waste are the critical contributors to the propagation of waste. Other wastes also have reduced, yet not negligible, effects. Waste due to Extra-processing contributes 13.01%, while defect waste accounts for 11.64%. Non-utilization of talents and Waiting have the least impact, with a score of 5.48% and 4.79%, respectively. As mentioned in Table 2, each type of waste is examined through a set of questions designed to find out gaps within the educational system. Based on the results above (Tables 4 and 8), Table 9 outlines inefficiencies related to the four critical MUDA identified and their potential impact on the effectiveness of training provided by ENSA.

Table 9. Inefficiencies/gaps identified

MUDA	Gap detected	Potential Impact
Transportation	• Weak collaboration between academic institutions and industry • Insufficient mechanisms for partnerships and knowledge exchange between academic universities and industry	• Educational programs remain outdated and not aligned with industry expectations • Inefficient correspondence between the program contents and professional practice
Inventory	• Overloaded programs without prioritization of key competencies • Ineffective teaching materials, tools, and pedagogical practices	• Poor competency mapping • Cognitive overload and weak professional readiness
Motion	• Possible rigidity or slow adaptability of the educational system	• Lack of continuous improvement initiatives • Weak curriculum review mechanisms • Need for dynamic course updating
Over-production	• Mismatch between the number of graduates and the real needs of the labor market • Some subjects in the curriculum are not used effectively in professional settings.	• Inefficient course design • Need for curricular optimization • Poor strategic workforce planning

The major inefficiencies concern mainly:

- Strategic alignment of education content with current and future labor market needs.
- Curriculum relevance and competency mapping;
- Industry – University collaboration mechanisms;
- Technological adaptation and pedagogical optimization.

4.4. The Proposed Hybrid Educational Model: OBEE-LEAN

The table below outlines the comparison between content-based learning, competency-based approach, and outcomes-based learning (OBEE). This comparison aids academic staff and stakeholders in grasping the implications of adopting either approach, offering insights into their respective impacts on knowledge acquisition, curriculum structure and design, learning material and teaching method, etc [33-35].

According to the results of the WAM, the OBEE approach is suggested as an effective solution. OBEE advocates the efficiency of the academic program by effectively engaging all stakeholders in the process of developing a flexible, responsive, and up-to-date curriculum that covers industry needs.

To foster the implementation of OBEE, Lean principles and methods are integrated at each level of OBEE.

Table 10. Comparison between traditional education, competency-based approach, and OBEE

Feature	Traditional Education /Content-Based Learning	Competency-Based Approach	Outcome-Based Learning (OBEE)
Knowledge acquisition	Rote-learning: Memory and content replication skills	Learning centered on action and experience: integrating knowledge, skills, and attitudes	Skills related to processes: Creative thinking, critical thinking, logical thinking, reflection, and action
Learning material and teaching method	• Education revolves around prescribed textbooks and worksheets, with a focus on teacher-directed instructions. • Traditional education often relies more heavily on teacher-directed instruction and passive learning methods.	• Learning is learner-centered and closely linked to real-world professional situations. • Based on case studies, projects, real-life situations, and contextualized learning	• Learning places the learner at the center, where the teacher facilitates and supports consistent teamwork to consolidate the new approaches. • OBEE promotes the implementation of active learning techniques that prioritize students, including problem-based learning and collaborative projects, to engage students and facilitate the achievement of outcomes
Curriculum design and structure	• The curriculum is divided into subjects based on content • Personal and professional education is frequently limited to certain periods of life • The teacher perceives the syllabus/curriculum as rigid and resistant to any form of negotiation • Traditional education typically follows a linear approach, starting with content and moving toward assessments	• Content is organized around competency blocks that integrate multiple domains of applied knowledge • Learning program is flexible and adaptable to labor market needs and professional developments • Curriculum design is centered on the development of essential competencies that students must acquire to succeed in professional contexts	• The curriculum is cohesive, making sure that the content is pertinent and connected to actual professional experiences and lifelong development • Learning programs are considered guidelines that empower teachers to foster innovation and creativity when they craft their courses • The design process for the curriculum begins with defining the intended outcomes and then progresses in reverse to establish instructional methods and evaluation criteria
Focus	Traditional education often focuses on the coverage of content and the delivery of instruction.	Acquisition of transversal and professional competencies to be used in real environments	OBEE emphasizes the achievement of specific and measurable outcomes
Assessment	Traditional education tends to rely more on standardized tests and summative assessments that measure content knowledge.	Evaluations are derived from real-world projects, real-life situations, and demonstrations of competency.	OBEE utilizes authentic, performance-based assessments that align with learning outcomes, providing meaningful feedback to students and teachers
Flexibility	Traditional education often adheres to fixed timelines and grade levels, regardless of individual student needs	A competency-based approach is flexible, with allowance for modifications based on need in the job market and student needs.	OBEE allows for flexibility, recognizing that learners progress at different paces

Accountability	Traditional education may place more emphasis on teacher accountability for delivering instruction.	The student has to prove themselves capable of using their knowledge in real-life scenarios.	OBEE holds both students and teachers accountable for achieving defined outcomes

4.4.1. Build Layer

Build Layer concerns the process of developing COs for all courses. A structured framework that connects course outcomes and lesson outcomes is created in this process [29]. The Delphi method was merged with the Régnier abacus to make the process more efficient and goal-oriented [36]. The Régnier abacus is a visual management tool that is extremely useful for the organization and presentation of the outcomes of the Delphi process. They highlight the suggestions and proposals made by the Delphi panel, displaying them using color-coded votes to describe the structure of trends and divergences. This visual synthesis of results gives an intuitive overview that supports decision-making and leads to conclusions that are easily digestible and accessible for all stakeholders. The Delphi panel consists of different stakeholders who are involved in the development and assessment of the COs. It includes Course Teachers (CT), Alumni (A), Subject Experts (SE), and Industry Professionals (IP). The role of each individual is presented in Table 11. Before starting, it is pivotal that the course teacher of the concerned institution/university precisely defines the objectives of the Delphi study and the specific subjects requiring the participation of the panel. This first step of the Delphi process ensures that the study remains focused and relevant. The Delphi method is a repetitive approach that typically consists of three rounds of feedback, though it may include additional rounds if necessary to achieve the highest level of agreement among the group. The progression of each round is illustrated in Figure 8 and Table 12. These rounds are conducted by the course teacher.

Table 11. Panel member role

Panel member	Role
Course teacher(s)	• Create and formulate lesson outcomes according to the total number of chapters in the entire course. • Engage and manage Delphi rounds to develop and evaluate course outcomes • Revise and reconstruct course outcomes based on the results of previous Delphi rounds
Alumni	• Bring insights and a practical perspective as individuals who moved into the professional world after completing the course. • Describe the challenges and difficulties they faced in the course/Subject.
Subject expert	• Identify main concepts, principles, and skills relevant to the subject. • Provide insight into the most interesting trends and developments. This helps in coming up with course outcomes reflecting cutting-edge knowledge and skills relevant to the subject/course. • Provide guidance for identifying additional skills or knowledge that the students could develop for continuous professional development.
Industry professionals	• Define key skills and capabilities that are significantly considered in the workplace. This helps in shaping the specific course outcomes to meet the employer's expectations. • Specify the application value of the knowledge and skills provided. This enables the course outcomes to extend beyond theoretical knowledge and prepares students for real-world challenges. • Guide graduates' employability. Their feedback is crucial in developing course outcomes toward better employability and work readiness. • Participate in the development of course outcomes that encompass the use of the current and appropriate equipment, software, and methodologies.

Table 12. Delphi rounds process

Round 1	Each panel member (course teacher, alumni, subject experts, and industry professionals) anonymously submits their proposals. After organizing the proposed COs, feedback, and recommendations are grouped, the Régnier abacus is used to assess the significance of each suggestion. This facilitates the visualization of the first trends and differences of the proposed COs.
Round 2	The synthesized proposals are presented to participants, who are invited to comment, modify, or suggest new CO on board. The Régnier abacus is then used a second time to provide a clear view of the evolution of consensus and priorities.
Round 3	Revised proposed COs are submitted for final validation. Each member uses the Régnier abacus to assign a final color to each proposal. This allows us to identify the most consensual results and establishes the final COs in a structured and visual way.

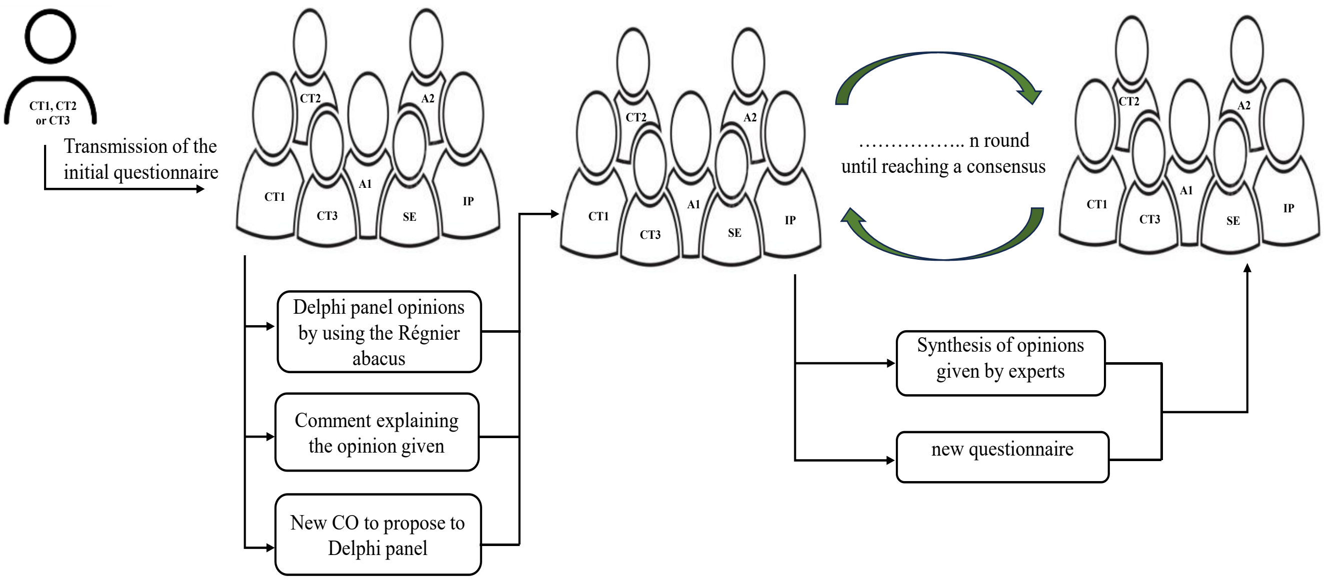

Fig. 8 Formulation and development of the delphi-régnier process

During each round, participants react individually to each suggestion by using color-coded votes of the Régnier abacus (Figure 9). Once a consensus is reached, the results from each round are compiled. Proposed COs are categorized from very much in favor (green) to very much against (red). This ranking enables the plotting of the curve of supporters and opponents. Based on this analysis, the final COs are determined. The proposed framework is conducted in the Department of Industrial and Logistics Engineering at ENSA of Marrakesh. The COs of the course Fluid Mechanics and Heat Transfer are presented (Tables 13,14, and 15). The Delphi panel consists of three Course Teachers (CT1, CT2, and CT3), two Alumni (A1 and A2), one Expert on the Subject (SE), and one Industry Professional (IP).

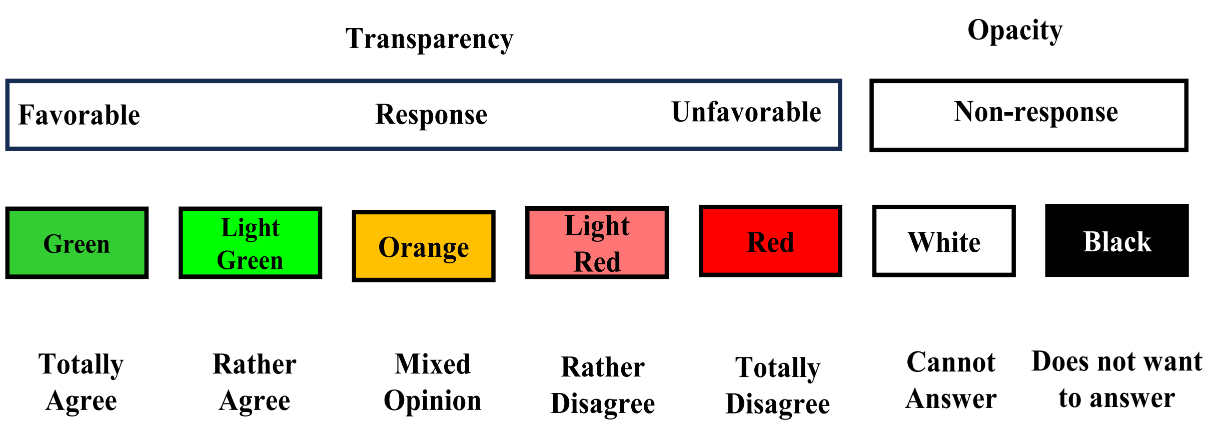

Fig. 9 Color-coded of Régnier abacus

Table 13. COs of round 1

No	CO	CT1	CT2	CT3	A1	A2	SE	IP
1	Understand basic concepts of fluid mechanics							
2	Examine fluid flow problems using momentum and energy equations.							
3	Examine issues related to pipe flow as well as fluid machinery.							
4	Examine turbo systems on different operating regimes.							
5	Determine the variations in fluid properties as temperature changes and analyze their impact on pressure and fluid dynamics.							
6	Describe fluid pressure and measurement methods.							
7	Describe how pressure correlates with elevation in relation to manometers, barometers, and various pressure-measuring instruments.							

8	Determine and calculate forces acting on a plane submerged in a static fluid.							
9	Determine and calculate the buoyant force acting on an object submerged in a static fluid.							
10	Use the general energy equation to determine changes in fluid flow through circular and non-circular pipes for incompressible fluids.							
11	Select an appropriate pump size and type to reach capacity and other pumping requirements.							
12	Present the physical idea of flow instability that results in the transition from laminar to external flow problems.							
13	Formulate Reynolds time-averaged Navier-Stokes equations and turbulent stress components.							
14	Analyze the mechanisms of heat and mass transfer occurring within complex internal flow systems.							
15	Analyze heat transfer within intricate internal flow systems.							
16	Understand the physical modeling aspects related to heat transfer.							

Table 14. COs of round 2

No	CO	CT1	CT2	CT3	A1	A2	SE	IP
1	Understand basic concepts in fluid mechanics							
2	Examine fluid flow problems using momentum and energy equations.							
3	Examine flow patterns and understand the effect of different flow regimes on the behavior of fluids.							
4	Understand the historical background, principles, formulation, and applications of fluid mechanics.							
5	Use Bernoulli's equation for real-world fluid flow problems.							
6	Understand principles of mass, momentum, and energy conservation in fluid dynamics.							
7	Understand the viscosity and turbulence effects on the fluid flow characteristics.							
8	Understand the principles of creeping flow and hydrodynamic lubrication.							
9	Design and analyze fluid systems such as pumps and pipelines							
10	Employ fluid mechanics concepts in the analysis of real systems.							
11	Solve boundary layer equations for laminar flow models.							
12	Identify types of convection problems and implement the principles of natural and forced convection for corresponding problems.							
13	Explain the different principles governing radiation heat transfer and calculate the radiation heat transfer occurring between black and grey surfaces in a basic mechanical system.							
14	Make appropriate choices regarding the use of exact or estimated calculations to address heat transfer problems in complicated systems.							

Table 15. COs of round 3 & Final COs

No		CO	CT1	CT2	CT3	A1	A2	SE	IP
curve of supporters: Final	1	Define and understand the fluid flow problems using a set of governing parameters.							
	2	Design experiments in the field of fluid mechanics							
	3	Examine flow patterns and identify flow regimes and their impacts.							
	4	Comprehend the physical modeling aspects of heat transfer and make the appropriate choice between exact and approximate calculations in solving complicated heat transfer problems.							
	5	Identify the analogy of flow and momentum diffusion to heat transfer, and determine the interdisciplinary character of thermal engineering problems.							

	6	Analyze heat transfer in complex internal flow systems and boundary layers, and external flow configurations.							
7		Select an appropriate pump size and type to reach capacity and other pumping requirements.							
8		Use the general energy equation to determine changes in fluid flow through circular and non-circular pipes for incompressible fluids.							
9		Employ fluid mechanics concepts in the analysis of real systems.							
10		Analyze heat transfer within intricate internal flow systems.							
11		Understand basic concepts in fluid mechanics.							
12		Describe how pressure correlates with elevation in relation to manometers, barometers, and various pressure-measuring instruments.							
13		Formulate Reynolds time-averaged Navier-Stokes equations and turbulent stress components.							
14		Understand the physical modeling aspects related to heat transfer.							
15		Understand the historical background, principles, formulation, and applications of fluid mechanics.							
16		Understand principles of mass, momentum, and energy conservation in fluid dynamics.							
17		Determine and calculate the buoyant force acting on an object submerged in a static fluid.							
18		Explain the different principles governing radiation heat transfer and calculate the radiation heat transfer occurring between black and grey surfaces in a basic mechanical system.							
19		Solve boundary layer equations for laminar flow models.							
20		Make appropriate choices regarding the use of exact or estimated calculations to address heat transfer problems in complicated systems.							
21		Examine fluid flow problems using momentum and energy equations.							
22		Examine issues related to pipe flow as well as fluid machinery.							
23		Examine turbo systems on different operating regimes.							
24		Use Bernoulli's equation for real-world fluid flow problems.							
25		Determine and calculate forces acting on a plane submerged in a static fluid.							
26		Present the physical idea of flow instability that results in the transition from laminar to external flow problems.							
27		Design and analyze fluid systems such as pumps and pipelines							
28		Understand the viscosity and turbulence effects on the fluid flow characteristics.							
29		Identify types of convection problems and implement the principles of natural and forced convection for corresponding problems.							
30		Determine the variations in fluid properties as temperature changes and analyze their impact on pressure and fluid dynamics.							
31		Describe fluid pressure and measurement methods.							
32		Analyze the mechanisms of heat and mass transfer occurring within complex internal flow systems.							
33		Understand the principles of creeping flow and hydrodynamic lubrication.							

5. Discussion

The hybrid educational model based on the combination of OBEE and Lean Management provides new, valuable insights for the improvement of engineering education. The adoption of Lean philosophy in the learning process serves as a gap filler for the traditional educational systems that do not generally take into account the efficiency in the process, value-added, and waste elimination. The WAM, developed as part of this framework, is an effective diagnostic tool to determine inefficiencies and gaps in academic programs regarding job market needs. This WAM enables institutions to visualize hidden waste – or more accurately, barriers to learning outcomes and academic program efficiency – by mapping the eight types of waste (Muda) from Lean Management in the context of education. For instance, forms of educational "Transportation" such as the effectiveness of the interactions between an educational institution and industry that can be assessed by the relevance and currency of academic programs, the strength of the partnerships formed, and the provision of internships and collaborative projects that meet the specific needs of the market, "Inventory" in the form of courses that focus on theory without providing enough opportunities for practical case studies, or "Motion" as regular changes in industrial engineering training that enhance the quality of education by ensuring that the curriculum remains relevant and aligned with the latest industry trends and practices. In addition, the paper introduces the first layer of the Lean-OBEE model developed. In this research, the Delphi method combined with the Régnier abacus forms an innovative way towards the development of COs. The process also encourages involvement of Industry Professionals, Domain Experts, and Alumni, which provides an appropriate theoretical and practically focused form to the documented COs. The proposed approach ensures that defined COs are reliable, specific, and well aligned with the stakeholders' requirements. The suggested hybrid model promotes the alignment of academic objectives and industrial needs. By embedding Lean principles in curriculum design and evaluation, the model enhances employment.

6. Conclusion

The present study aimed to assess the quality and relevance of the training provided to industrial engineering students through a Waste Assessment Model (WAM). The analysis identified four major Muda: Transportation (18.49%), Inventory (16.44%), Motion and Over-production (15.07%). To tackle these wastes, an innovative educational model that integrates Lean Management into OBEE architecture is proposed. This hybrid framework seeks to enhance the alignment and adequacy of educational outcomes and industrial needs by supplying skilled and competent industrial and logistics engineers who can be seamlessly absorbed by the job market. In this paper, only the first layer is presented, "The Build layer." Future publications will address the subsequent layers of the proposed model.

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